

# The NASA Lightning Nitrogen Oxides Model (LNOM): Recent Updates & Applications

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photo by Chuck Doswell

# LNOM

- ❑ Filtration of VHF Sources
- ❑ Flash-Typing
- ❑ Transformations, Spatial Averaging, and Sorting of VHF Sources
- ❑ Channel Length Computation
- ❑ Channel Segment Creation
  - location
  - polar angle
- ❑ NO<sub>x</sub> Computation
  - Lab [Wang et al., 1998]
  - Theory [Cooray et al. 2009]

**Channel  
Length  
Distributions**

**Segment  
Altitude  
Distributions**

**Lightning  
NO<sub>x</sub>  
Profiles**

**Flash-Specific  
Results**

**Ancillary  
Analyses**

**VHF  
data**

**McCaul  
Clustering  
Algorithm**

**Clustered  
VHF data**

**NLDN  
data**

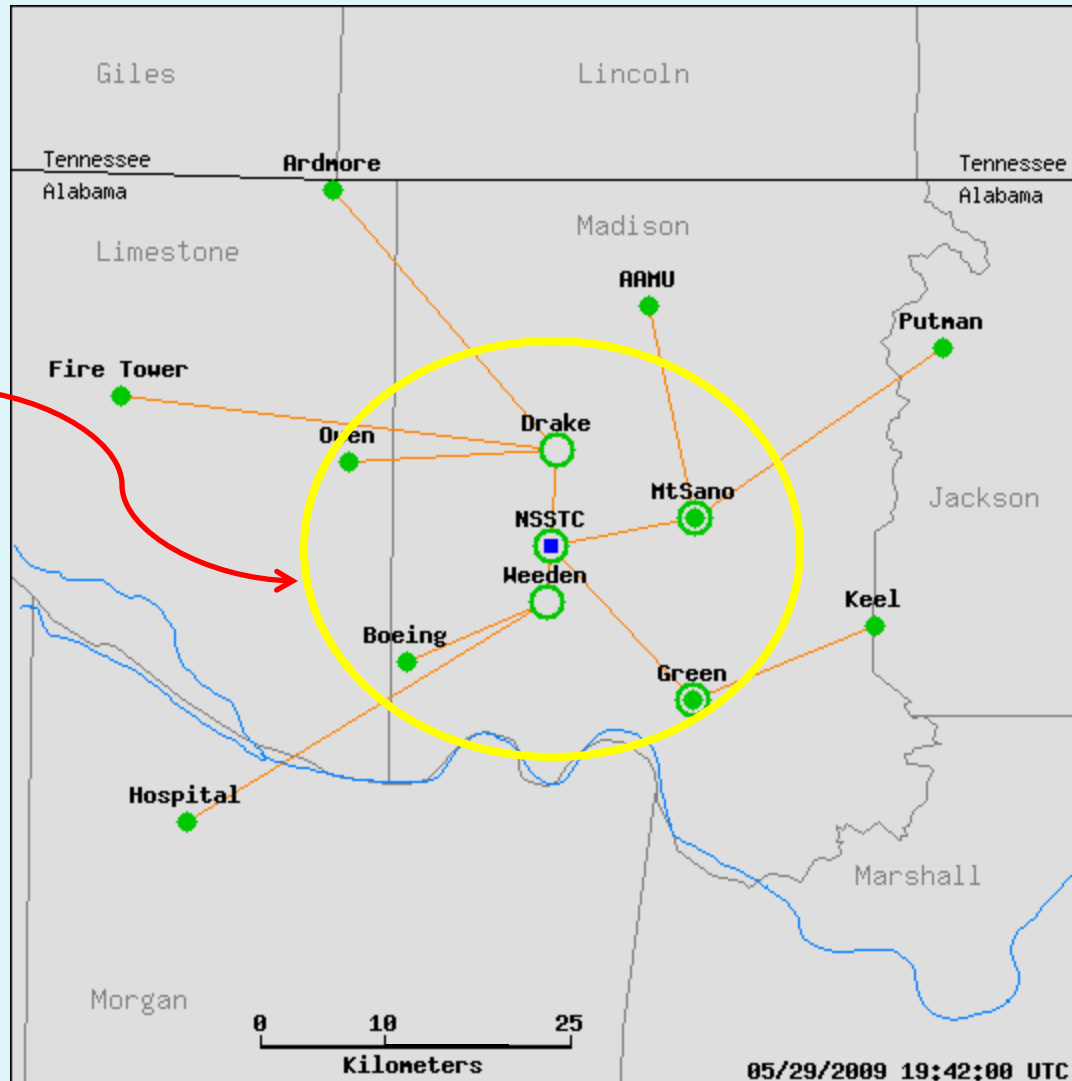
# NALMA Network

LNOM  
Analysis  
Cylinder

(vertical extent  
is 0-21km)

Mimics a  
CMAQ grid  
volume.

Examine all  
flashes in  
cylinder for  
August 2006.



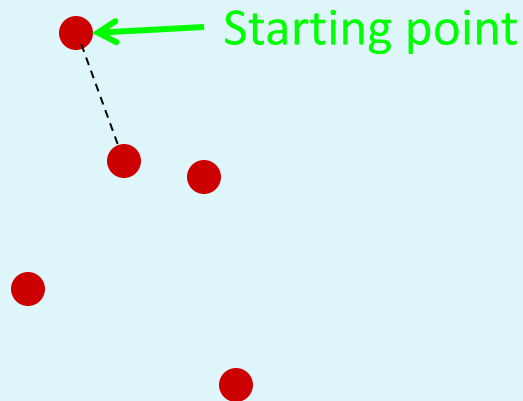
 Router

# Initial Processing

1. McCaul VHF Source Clustering Algorithm
  - ✓ Ingests LMA data
  - ✓ Clusters ( $\chi^2 < 2$ ) vhf sources into “Things”
    - “Things” are: Flashes, Small (Non-lightning) Discharges, Noise
2. LNOM “Thing” Filtration
  - ✓ Range Filter (remove “thing” if completely outside cylinder)
  - ✓ Number Filter (remove “thing” if  $< 20$  vhf sources... e.g., singletons)
  - ✓ **What remains: legitimate flashes that are at least partially in cylinder**
3. LNOM VHF Source Filtration
  - ✓ Power Filter (remove vhf source if power  $< 1$  dBW)
  - ✓ Altitude Filter (remove vhf source if at sfc or  $\geq 20$  km)
4. LNOM Flash-Type Categorization
  - ✓ Deemed a CG if a NLDN CG detection is within (100 ms, 10 km), and lowest altitude vhf is below N-region height.
  - ✓ But, deemed ambiguous if peak current is between 10 - 20 kA.
5. LNOM Processing of VHF Sources in Legitimate Flashes
  - ✓ Coordinate Transformation
  - ✓ Spatial Averaging
  - ✓ Sorting

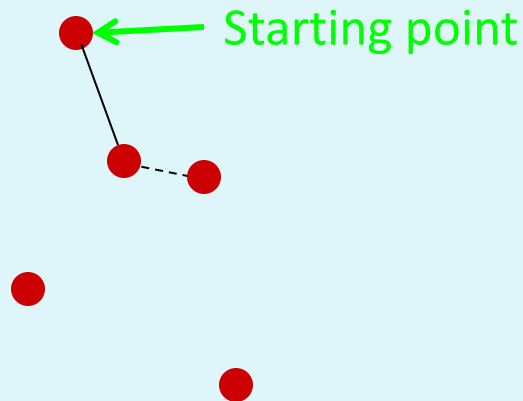
# Channel Length Algorithm

- Begin with  $n$  averaging points ( $n = 5$  in example below)
- 1<sup>st</sup> Iteration:
  - Start at the highest altitude point. Define it to be “on the channel”, and all other points to be “free” (off channel).
  - Draw line from starting point to closest free point. This is the first channel “section”.
  - Now there are 2 points on the channel, and  $n-2$  free points

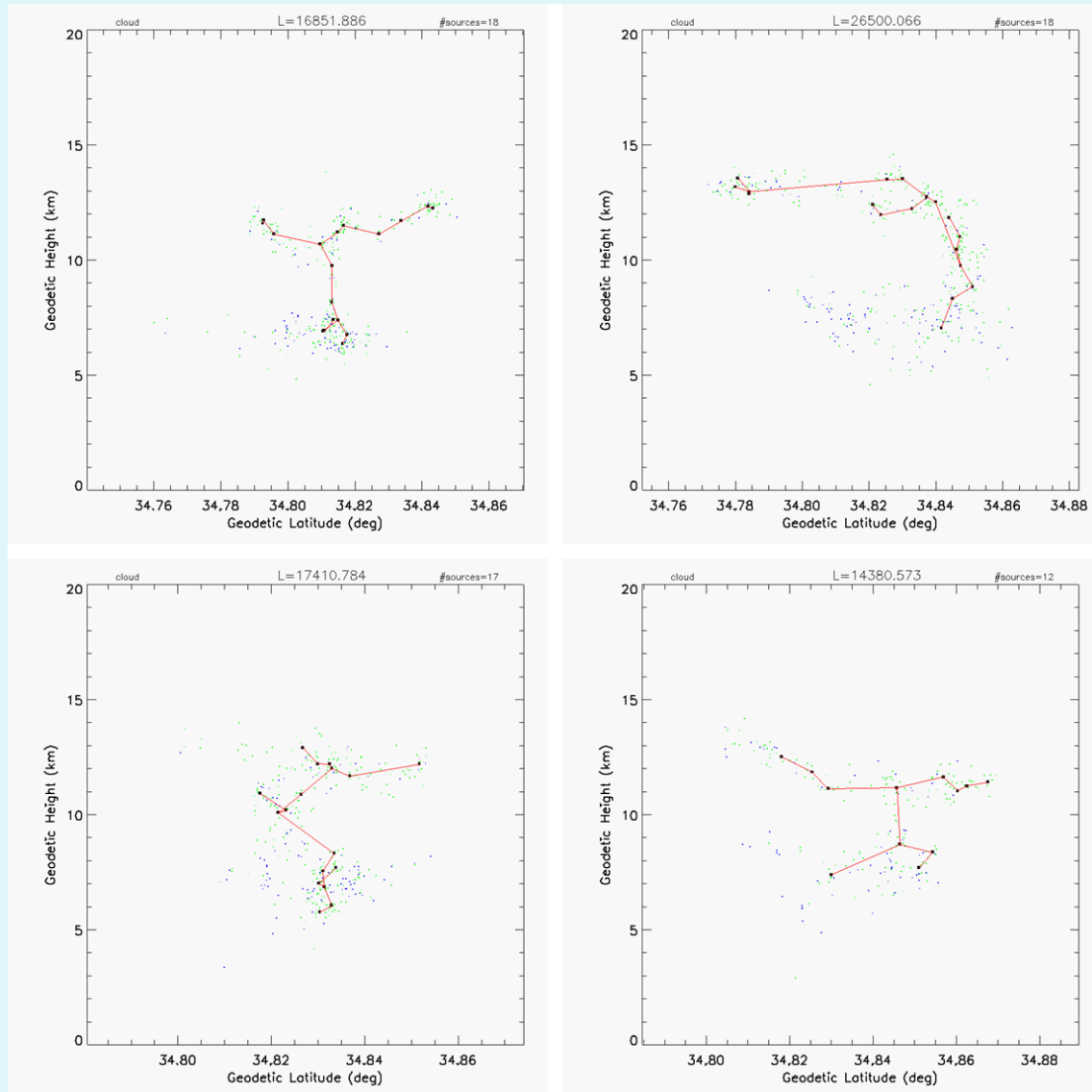


## Channel Length Algorithm (cont.)

- 2<sup>nd</sup> Iteration:
  - Find closest free point to 1<sup>st</sup> channel point
  - Find closest free point to 2<sup>nd</sup> channel point
  - Pick min of the mins (i.e., draw line from a free point to a channel point that is the minimum distance).
- Continue with more iterations until no more free points

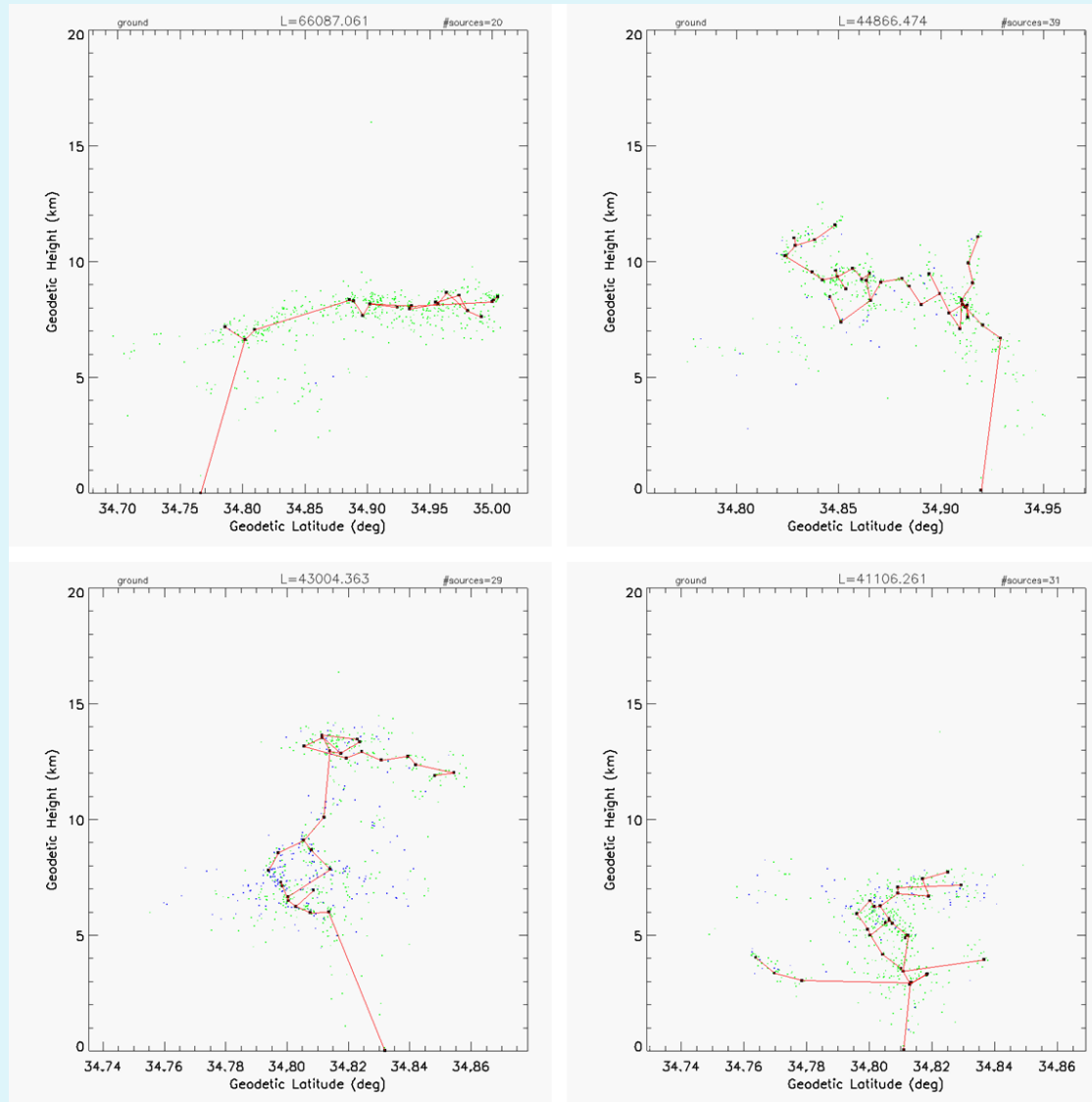


# Sample Cloud Flashes



**Figure 1.** Sample channel length,  $L$ , computed for 4 cloud flashes. Number of sources shown in upper right is the number of spatially averaged points (black dots). Green dots are the VHF sources that meet the 2 dBW power threshold, and the blue dots are those that do not.

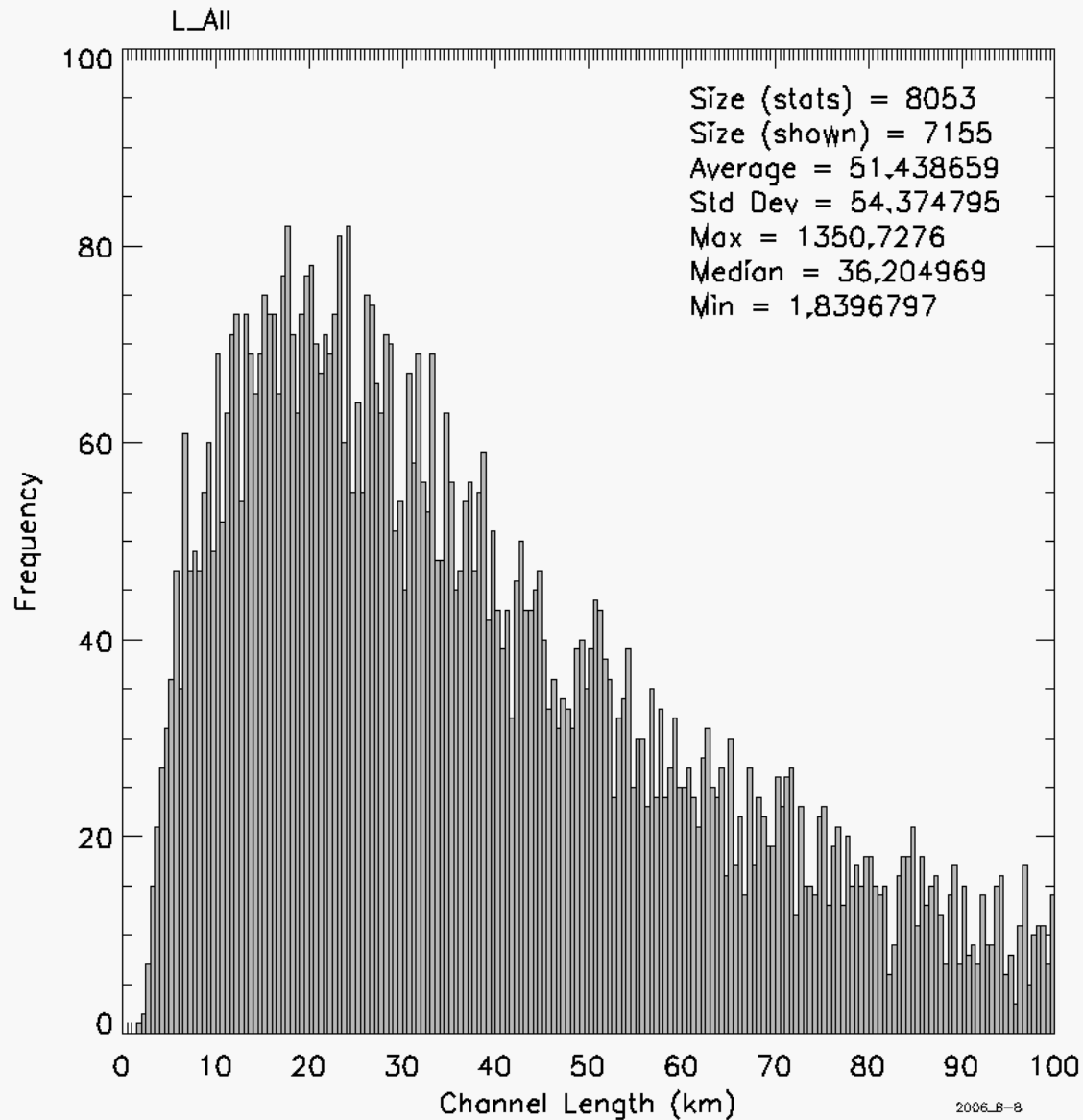
# Sample Ground Flashes



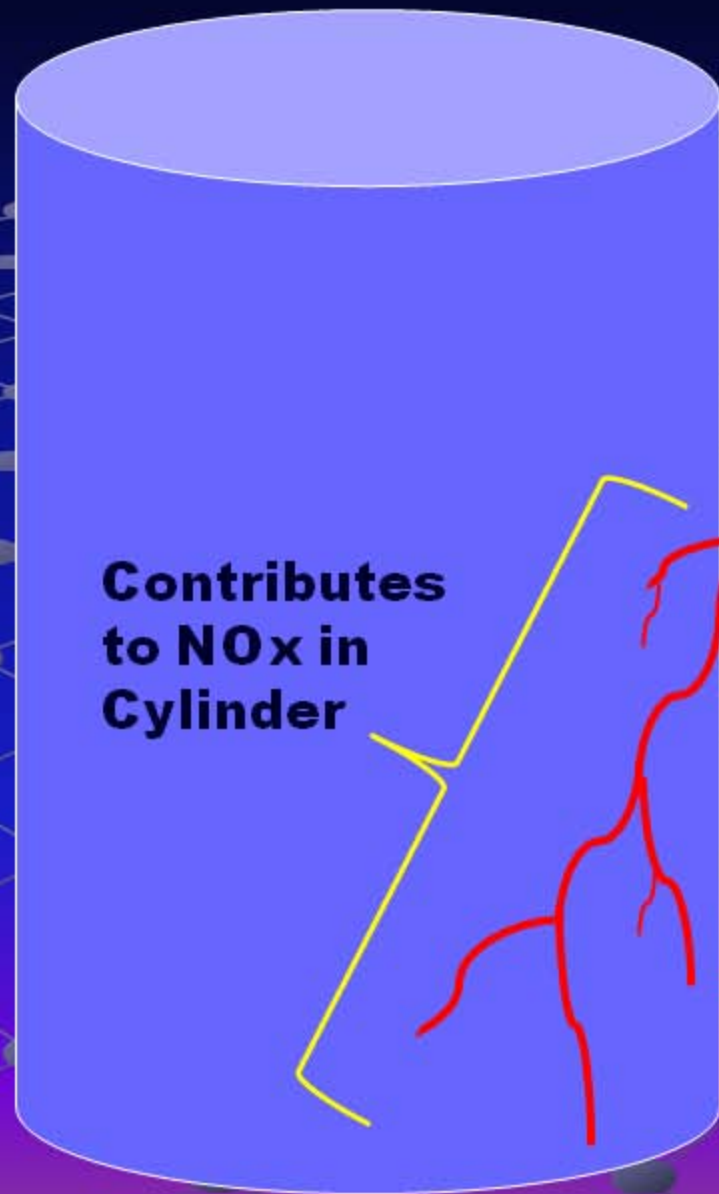
**Figure 2.** Sample channel length computations for 4 ground flashes.



# Channel length (August 2006)

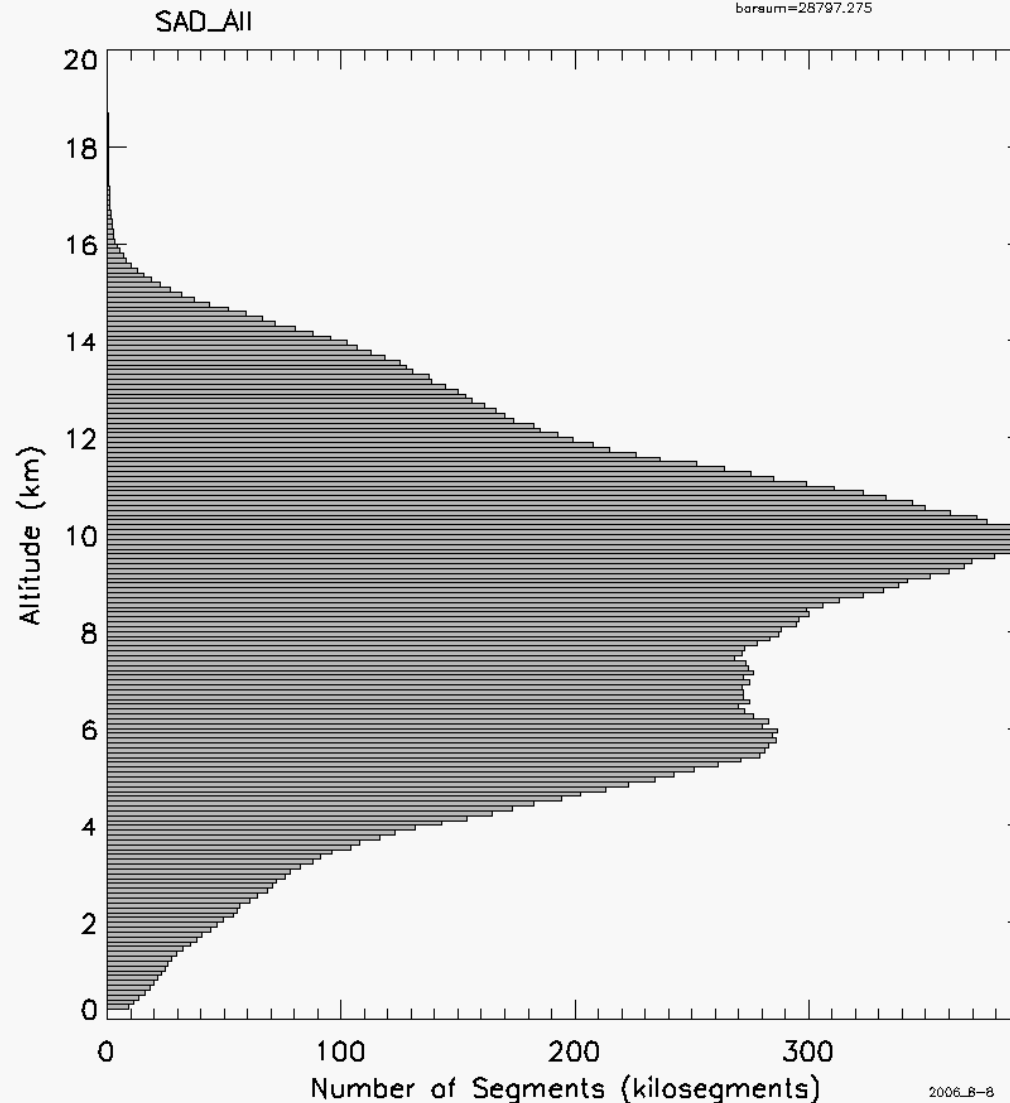


# Computing **S**egment **A**ltitude **D**istribution

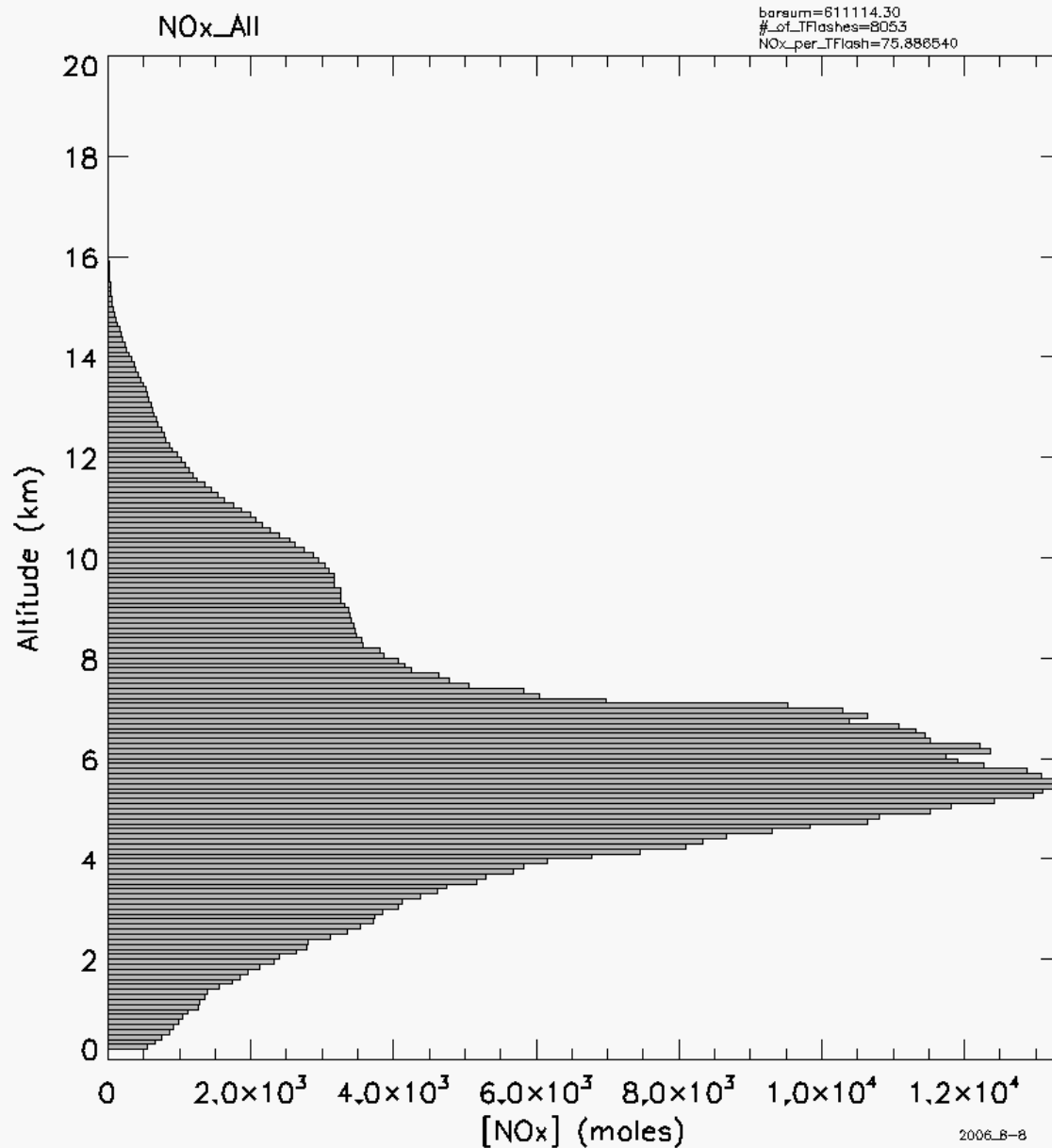


- Chop up Channel into 10-m Segments
- Tally segments in each **100 m** layer (only within cylinder)

# Segment altitude distribution (August 2006)



# NOx profile (August 2006)



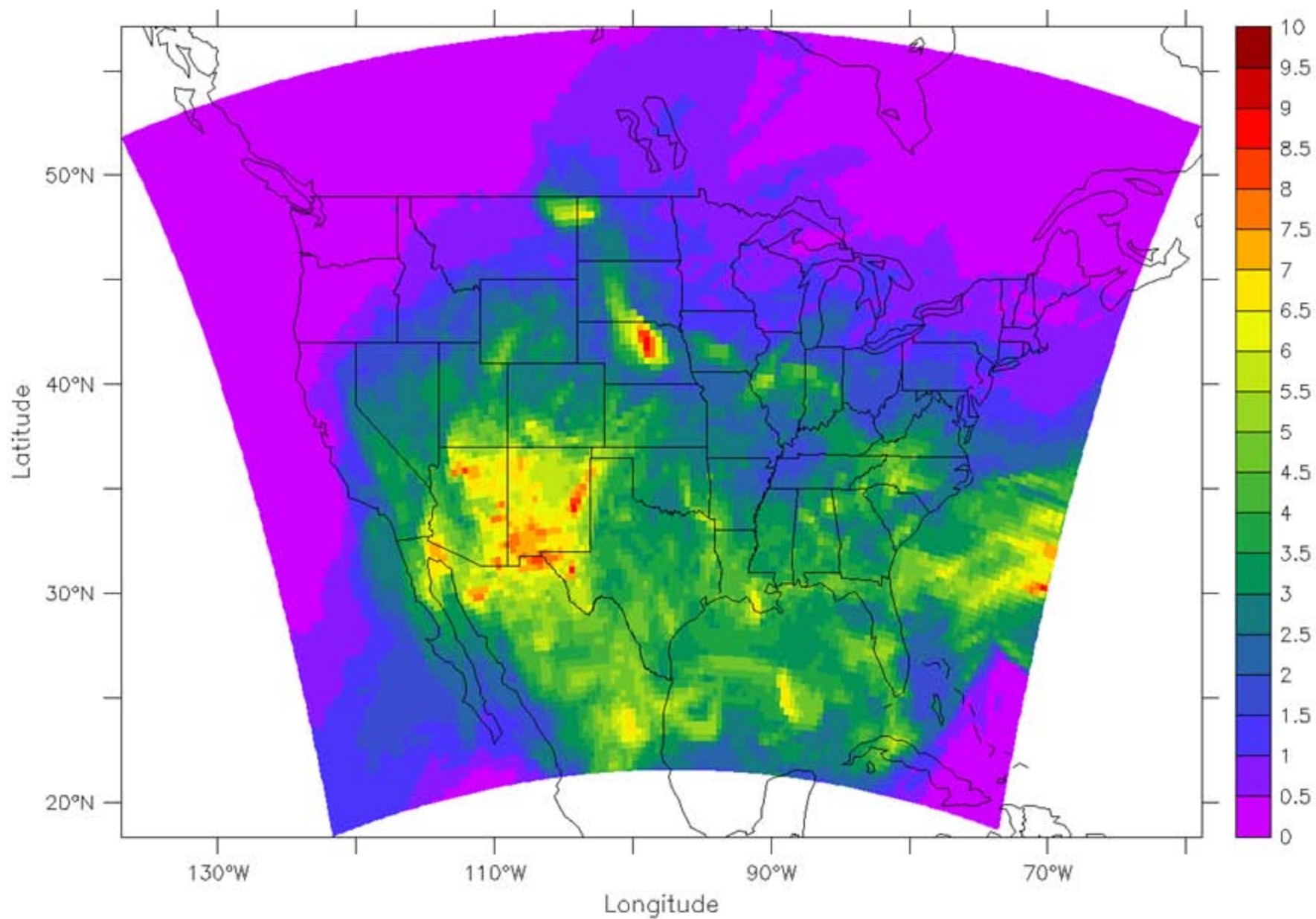


Figure 9. Maximum increase in surface  $O_3$  due to lightning  $NO_x$  (ppb).



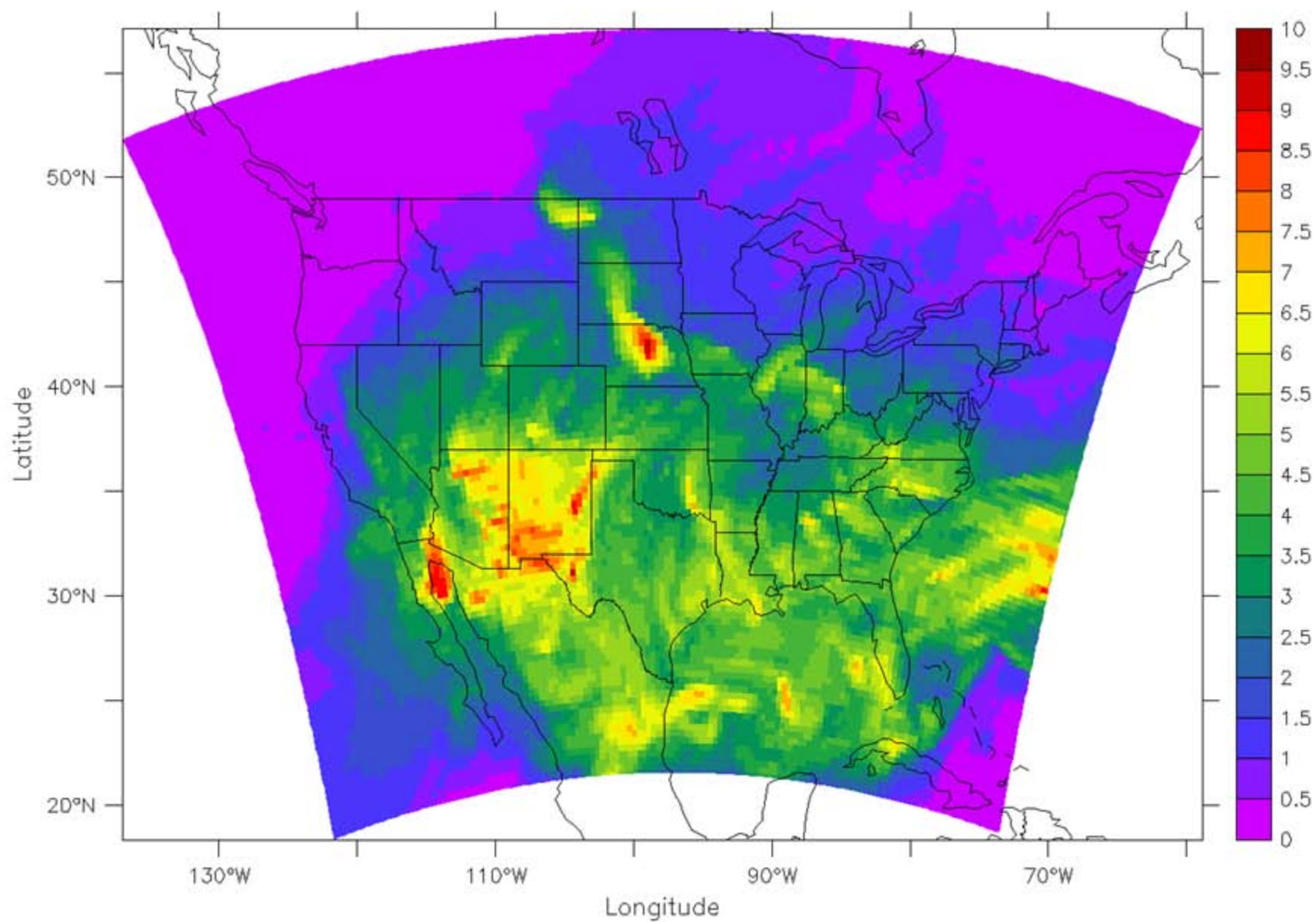


Figure 10. Maximum increase in boundary layer  $O_3$  due to lightning  $NO_x$  (ppb).

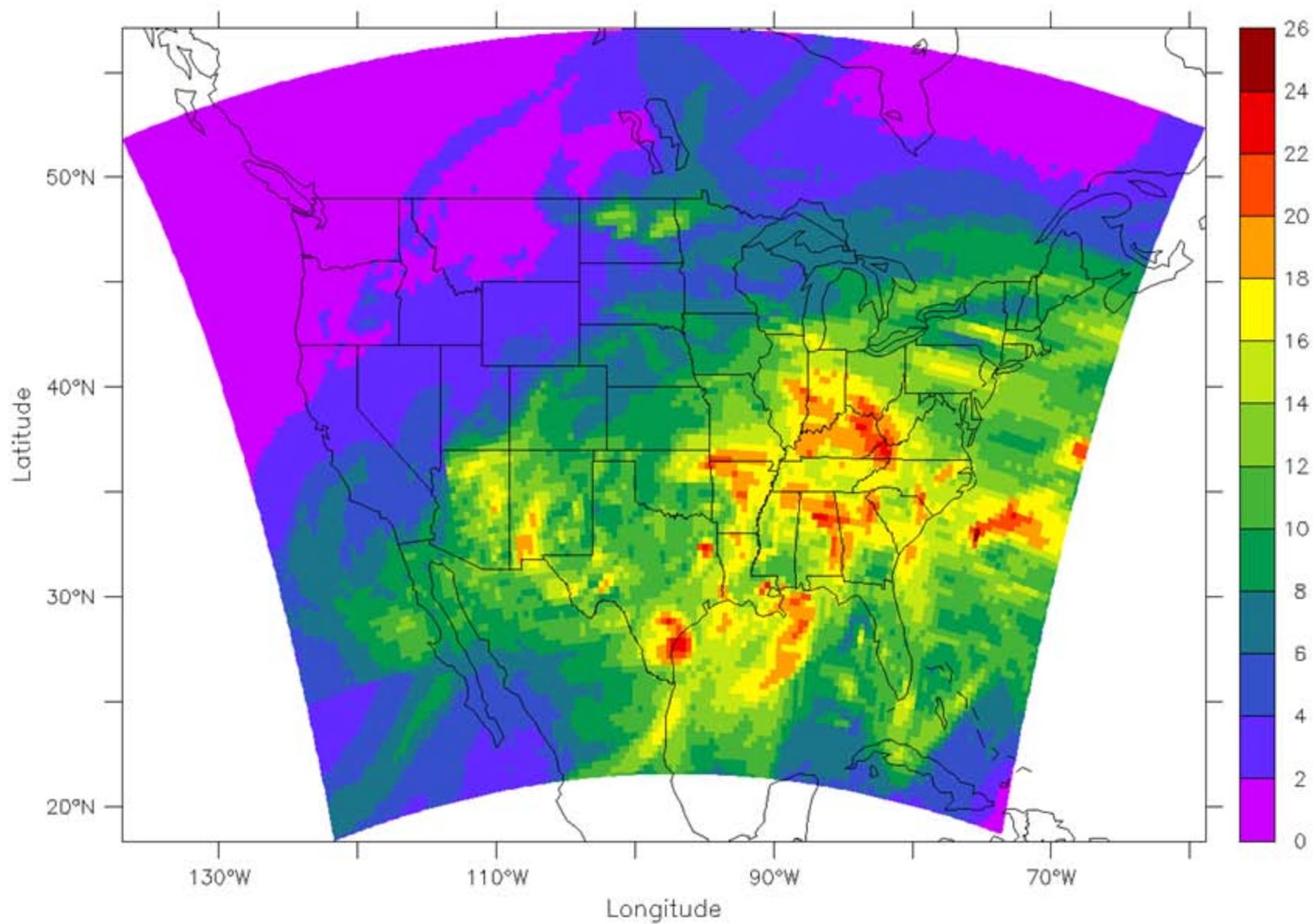
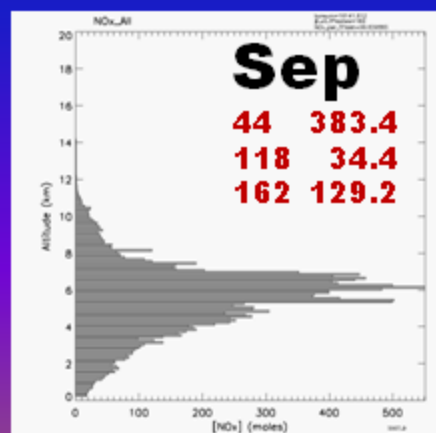
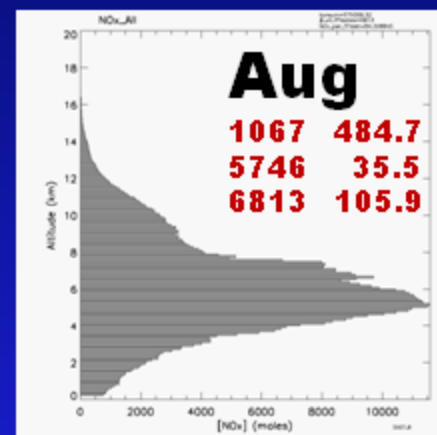
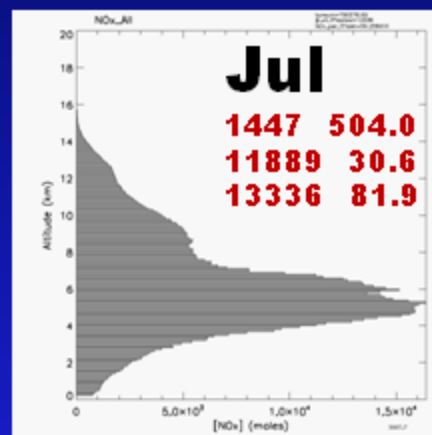
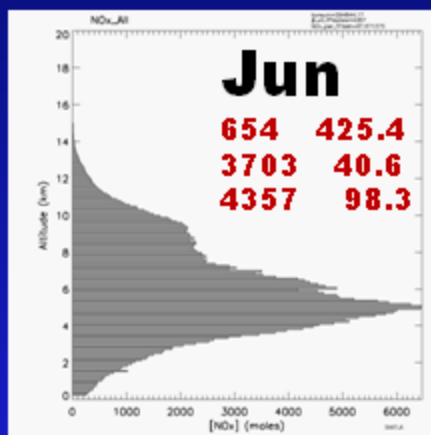
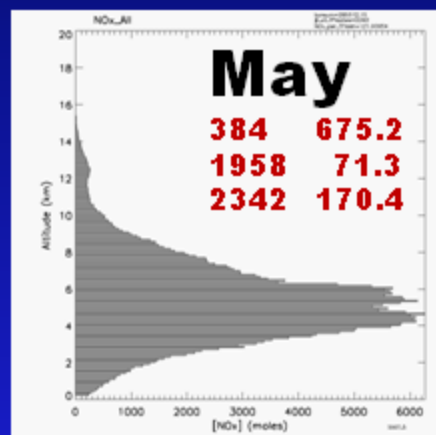
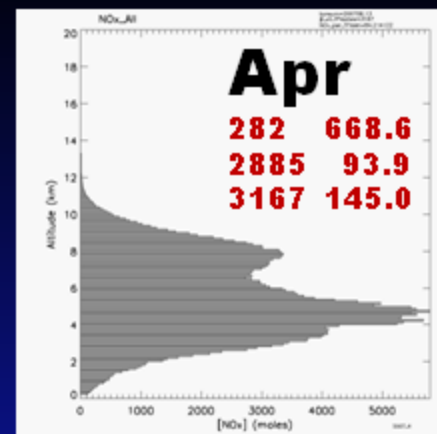
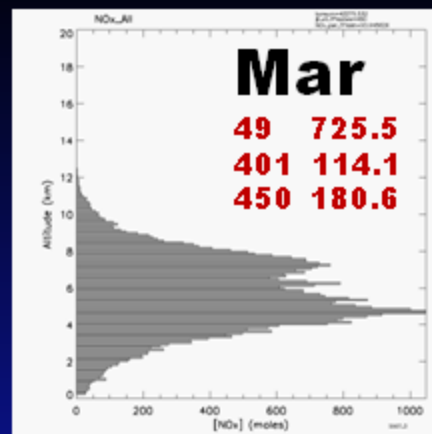
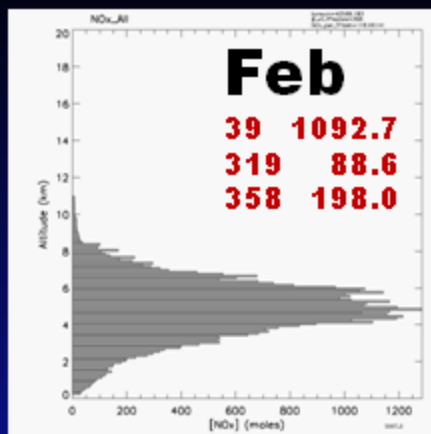
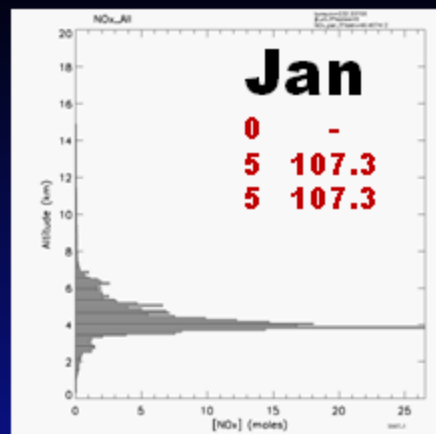
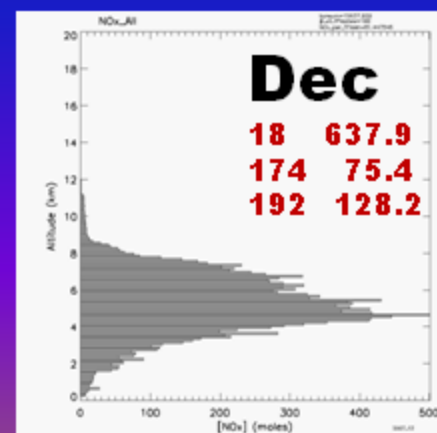
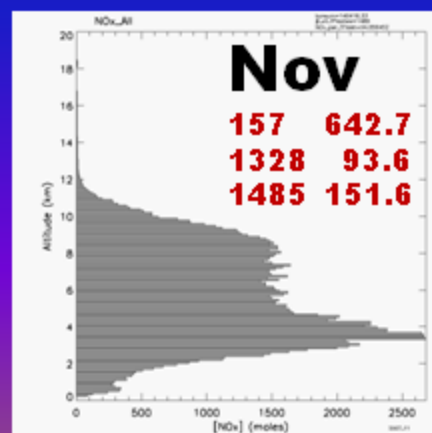


Figure 11. Maximum domain-wide increase in  $O_3$  due to lightning  $NO_x$  (ppb).

# NO<sub>x</sub> Profiles for all Months in 2007 (Latest LNO<sub>M</sub> Version)



**Oct**  
No flashes  
in LNO<sub>M</sub>  
analysis  
cylinder after  
filtration





# Desired Future Application

**# GLM  
Flashes**



**Ground Flash Fraction  
Retrieval Algorithm**

**(Koshak GOES-R Risk Reduction Activity)**

**GLM = Geostationary Lightning Mapper (on GOES-R)**



**Vital link**

**MSFC LNOM  
(lightning NOx)**



**# GLM  
Ground  
Flashes**

**# GLM  
Cloud  
Flashes**



**Air Quality Models** (e.g. CMAQ)  
**Global Chemistry/Climate Models**  
(e.g. GISS Model E, Geos Chem)

# Additional Current/Future Work

- We have now completed all months in 2005, 2006, and 2007. Working on 2008, 2009, and 2010.
  - My work over the past several months has been to complete flash clustering analysis for 2005-2010.
  - Currently working on DCLMA analysis for 2007.
- LNOM results being made available to multiple research partners:
  - NASA GSFC
  - UAH
  - Georgia Tech
  - Harvard
  - NASA GISS
- LNOM results will be placed on Global Hydrology Resource Center (GHRC) website to better serve customers.